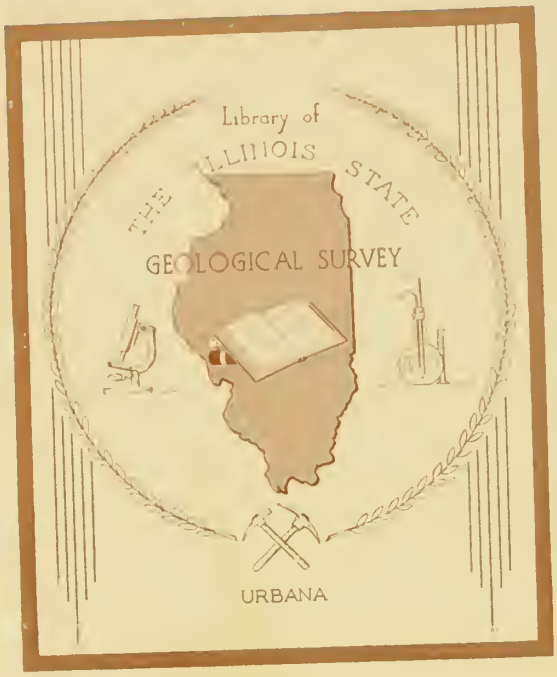


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# SUMMARY OF FINDINGS ON SOLID WASTE DISPOSAL SITES IN NORTHEASTERN ILLINOIS

G. M. Hughes, R. A. Landon, and R. N. Farvolden

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# SUMMARY OF FINDINGS ON SOLID WASTE DISPOSAL SITES IN NORTHEASTERN ILLINOIS

*G. M. Hughes, R. A. Landon,* and R. N. Farvolden†*

## INTRODUCTION

The landfill is the most commonly used approved method of solid waste disposal, and has replaced the open burning dump in most areas. A sanitary landfill is defined by the American Society of Civil Engineers as "...a method of disposing of refuse on land without creating nuisances or hazards to public health or safety by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation, or such more frequent intervals as may be necessary." (Am. Soc. Civil Engrs., 1959, p. 1). The definition implies that if a landfill is truly a "sanitary landfill" it will not adversely affect the quality of surface or ground water.

The results and conclusions of an investigation of the hydrogeology and geochemistry of five landfills (fig. 1) in northeastern Illinois are summarized here. The study was made to develop guidelines that could be used to evaluate the pollution potential of existing and proposed landfill sites. The investigation was supported in part by the Solid Waste Management Office, U. S. Environmental Protection Agency (formerly the Bureau of Solid Waste Management, U. S. Public Health Service, Department of Health, Education and Welfare), Grant no. G06-EC-00006. It was conducted mainly by personnel of the Illinois State Geological Survey and was sponsored by the Survey, the Illinois Department of Public Health, and the University of Illinois. The comprehensive

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TABLE 1—U. S. PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS AND COMPOSITION OF VARIOUS LIQUID WASTES
(in parts per million)

| Substance | U. S. Public Health Service standards[a] | | Leachate | | | Influent sewage[i] | Effluent sewage[i] | Slaughter-house wastes[j] | Chemical plant effluent[k] |
|---|---|---|---|---|---|---|---|---|---|
| | Group I[a,b,c] | Group II[d,e] | Blackwell[f] | LW5B Du Page[g] | LW6B Du Page[h] | | | | |
| Alkyl benzene sulfonate | 0.5 | | | 0.72 | 0.30 | | | | |
| Arsenic | 0.01 | 0.05 | 4.31 | < 0.10 | 4.6 | | | | |
| Chloride | 250 | | 1,697 | 1,330 | 135 | | | 320 | 1,070 |
| Copper | 1 | | 0.05 | < 0.05 | < 0.05 | 0.450 | 0.032 | | 2.1 |
| Carbon chloroform extract | 0.2 | | | | | | | | |
| Cyanide | 0.01 | 0.2 | 0.024 | < 0.005 | 0.02 | | 0.051 | | |
| Fluoride | | 3.4 | | 2 | 0.31 | | | | 800 |
| Iron | 0.3 | | 5,500 | 6.3 | 0.6 | 2.600 | 0.938 | | 51 |
| Manganese | 0.05 | | 1.66 | 0.06 | 0.06 | | | | 0.48 |
| Nitrate | 45 | | 1.70 | 0.70 | 1.60 | | | | 864 |
| Phenols | 0.001 | | | | | | | | |
| Sulfate | 250 | | 680 | 2 | 2 | | | 370 | 8,120 |
| Total dissolved solids | 500 | | 19,144 | 6,794 | 1,198 | | | 2,690 | 16,090 |
| Zinc | 5 | | | 0.13 | < 0.10 | 0.638 | 0.366 | | |
| Barium | | 1 | 8.5 | 0.80 | 0.30 | | | | |
| Cadmium | | 0.01 | < 0.05 | < 0.05 | < 0.05 | 0 | 0 | | |
| Chromium ($Cr^{+6}$) | | 0.05 | 0.20 | 0.15 | < 0.05 | 0 | 0 | | |
| Lead | | 0.05 | | 0.50 | 0.50 | 0.138 | 0.138 | | |
| Selenium | | 0.01 | 2.7 | < 0.10 | < 0.10 | | | | |
| Silver | | 0.05 | < 0.1 | < 0.1 | < 0.1 | | | | |
| Ammonium | | | | | | 19 | 16 | | 198 |
| Alkalinity (as $CaCO_3$) | | | 3,255 | 4,159 | 1,011 | | | 440 | 760 |
| Hardness (as $CaCO_3$) | | | 7,830 | 2,200 | 540 | | | | 0 |
| Phosphate | | | 6 | 1.20 | 8.90 | | | 66 | 74 |
| Titanium | | | | | | | | | 0.97 |
| Aluminum | | | 2.20 | 0.10 | 0.90 | | | | 6.4 |
| Sodium | | | 900 | 810 | 74 | | | | 6,190 |
| Hexane solubles | | | 350 | 18 | 7 | 22.4 | 11 | | |
| Biological oxygen demand[l] | | | 54,610 | 14,080 | 225 | 104 | 17 | 3,700 | |
| Chemical oxygen demand | | | 39,680 | 8,000 | 40 | 240 | 70 | 8,620 | |
| pH | | | | 6.3 | 7.0 | 7.2 | 7.4 | 8.1 | 6.2 |

[a] U. S. Department of Health, Education and Welfare (1962).
[b] Nitrates exceeding 45 ppm dangerous for infants.
[c] Should not be used if more suitable supplies available.
[d] Larger concentrations should be rejected.
[e] Fluoride is temperature dependent.
[f] Probably represents leachate from compaction and infiltration.
[g] Leachate from refuse about 6 years old.
[h] Leachate from refuse about 17 years old.
[i] Data provided by Metropolitan Sanitary District of Greater Chicago.
[j] Data from files of the Illinois Department of Public Health.
[k] Rare earth and thorium production (Butler, 1965, p. 63).
[l] Twenty-day biological oxygen demand for leachate. Other values are 5-day BOD.

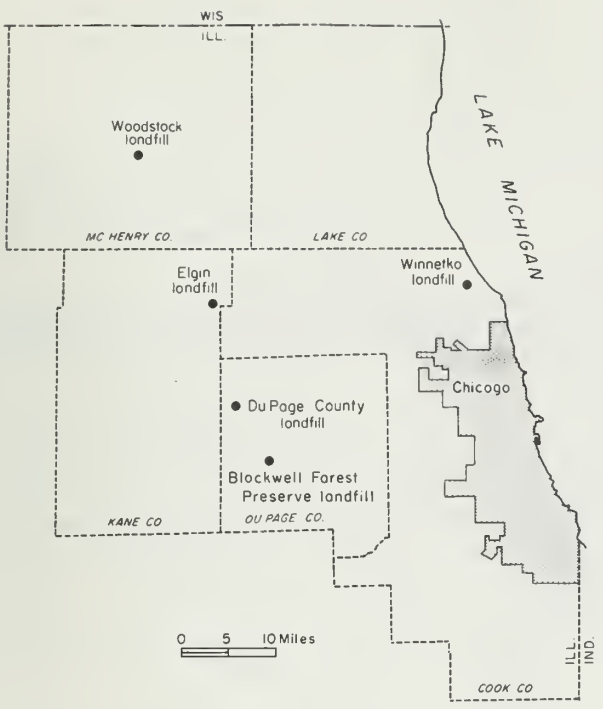



Fig. 1 - Locations of landfill sites investigated.

report for this investigation is being published by the Solid Waste Management Office. Some of the data from the study were published by the Geological Survey in 1969 (Hughes, Landon, and Farvolden).

For the investigation, well points and piezometers were installed around and below existing landfills to determine the pattern of ground-water flow, and samples of ground water were gathered from selected points and analyzed. Data were collected on the composition of dissolved solids in water draining from the refuse (leachate) and on the attenuation of the various dissolved solids in the leachate as it moved away from the disposal site.

The data suggest that large areas of northeastern Illinois could be used for solid waste disposal without affecting the ground-water resource. Methods of designing and operating landfill facilities in various hydrogeologic environments also were suggested by the findings of the study.

## FINDINGS OF PREVIOUS INVESTIGATIONS

Previous investigations of landfills in Europe and the United States have brought out the following facts.

1. A leachate capable of polluting ground and surface water is commonly produced by refuse in contact with water. (The composition of such leachate is compared with that of other liquid wastes in table 1.) The water that leaches the refuse may be ground water or infiltrating precipitation. In an arid climate, such as that of southern California, precipitation is not adequate to infiltrate and produce a leachate from buried refuse. Refuse buried above the top of the zone of saturation in such areas will not endanger ground-water resources unless the area is flooded. In a wet climate, such as is found in Britain, however, investigations have shown that precipitation will infiltrate refuse and produce leachate.

2. Dissolved solids in leachate travel with the ground water and may, under certain circumstances, so degrade the ground water that it can no longer be used for domestic purposes.

3. Gases, predominantly methane and carbon dioxide, also are produced by the decomposition of refuse. Methane may cause explosions, and carbon dioxide may increase the hardness of the ground water.

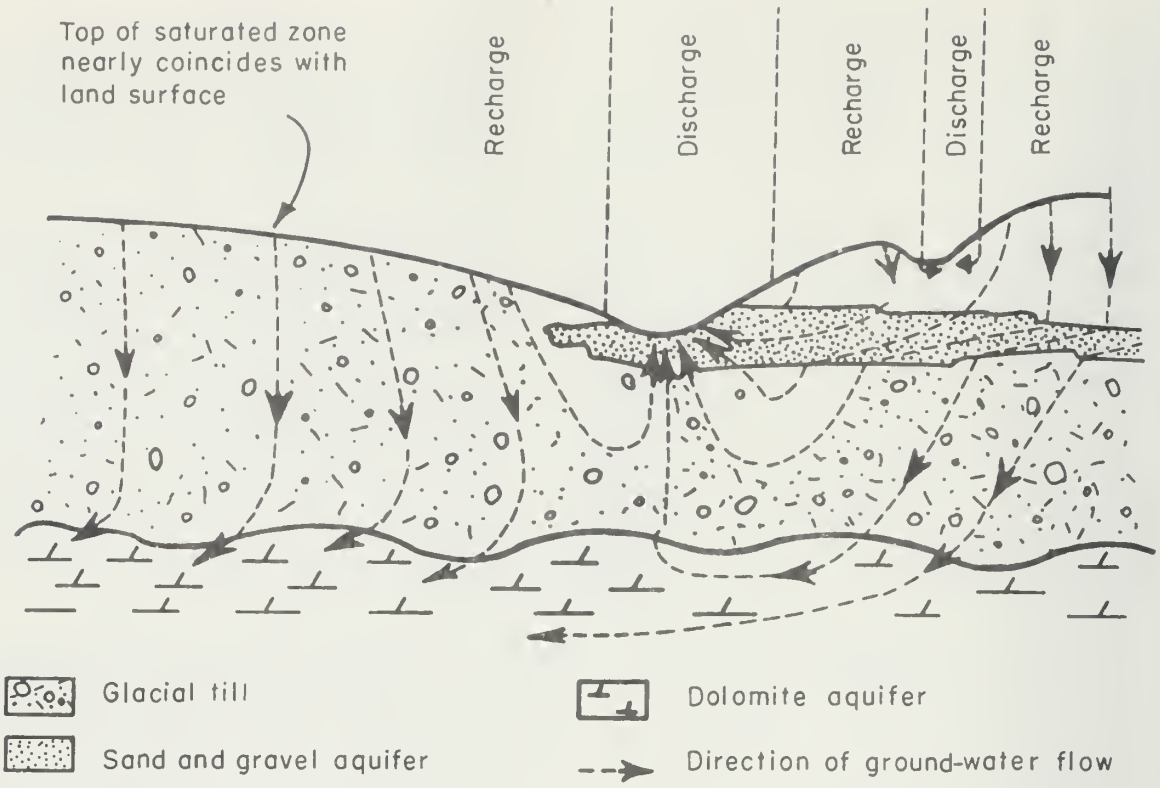



Fig. 2 - Hypothetical system of ground-water flow.

4. The length of time required for refuse to stabilize and cease producing contaminants cannot readily be predicted. The process is dependent upon a number of factors, including the moisture available, the temperature, the materials present in the landfill, and probably upon the conditions of burial and compaction. Some landfills stabilize in a few years; others still produce methane after 30 years.

## METHODS OF INVESTIGATION

A ground-water flow system is the path water takes through the earth. In the subsurface of a humid region such as northeastern Illinois, the top of the zone of saturation, or water table, is close to the land surface. Ground water occupies all the openings in the earth material below the water table. Above the water table the openings are filled with both water and air. A part of the precipitation or other water that has entered the ground moves downward to the water table and enters (recharges) the ground-water flow system. This water moves through the ground to a point of discharge at the earth's surface, such as a stream, swamp, marsh, or lake (fig. 2).

To trace contaminants from a disposal site into the surrounding earth materials, it was necessary to delineate, both quantitatively and qualitatively the ground-water flow system operating at the site. This involved determining

how much water was going into the landfill, how much leachate was leaving the landfill, and what paths the water and leachate followed.

Five sites were studied during our investigation. Existing sites were chosen because the leachate leaving them can be traced, and because landfills of various ages provide a record of changes in the composition of the leachate over a considerable time period. They also were in environments typical of those likely to be used for future landfills.

During the investigation, 274 piezometers and sampling points were installed at the five sites. A piezometer is a screen or permeable plastic tip fastened to the end of a pipe or tube. The pipe is installed in a boring, and the opening around the pipe above the tip is sealed with bentonite. Water enters the pipe from the ground through the tip. Water-level measurements in the pipe and water samples recovered from the pipe are used to determine the pressure and quality of water in the restricted zone around the piezometer. Water from higher in the boring cannot enter the pipe because it is sealed off by the bentonite. A well point is similar to a piezometer, except that there is no seal to restrict water movement around the outside of the pipe and, therefore, measurements or water samples obtained from a well point may reflect conditions throughout a large vertical interval instead of at a particular point.

Water analyses were performed by the Illinois Department of Public Health, commercial laboratories, and the Illinois State Geological Survey. The Survey also made the analyses of the earth materials associated with the landfills. Monthly, weekly, and continuous hydrographs of water levels were compiled, together with records of barometric changes and precipitation. Permeability data were gathered from tests performed in the field and in the laboratory.

## RESULTS OF INVESTIGATION

### Old Du Page County Landfill

The old Du Page County landfill is located in the NW¼ Sec. 32, T. 40 N., R. 9 E., Du Page County. It is in a flat upland area that was originally swampy but was drained through tiles into Kress Creek, which flows to the south along the eastern side of the landfill area. The general sequence of earth materials in the area consists of an upper surficial sand, 10 to 20 feet thick, overlying approximately 55 feet of silty and sandy clay till that contains one thin, interbedded sand unit. The till overlies the dolomite bedrock, which is a major aquifer in this area.

Filling by the trench and fill method began in 1952 and was completed in 1966. Some of the trenches intersected the top of the zone of saturation. The refuse was piled to a maximum thickness of 20 feet. The final fill cover was 2 to 3 feet thick and consisted primarily of silt loam, clay, silty clay loam, and clay loam.

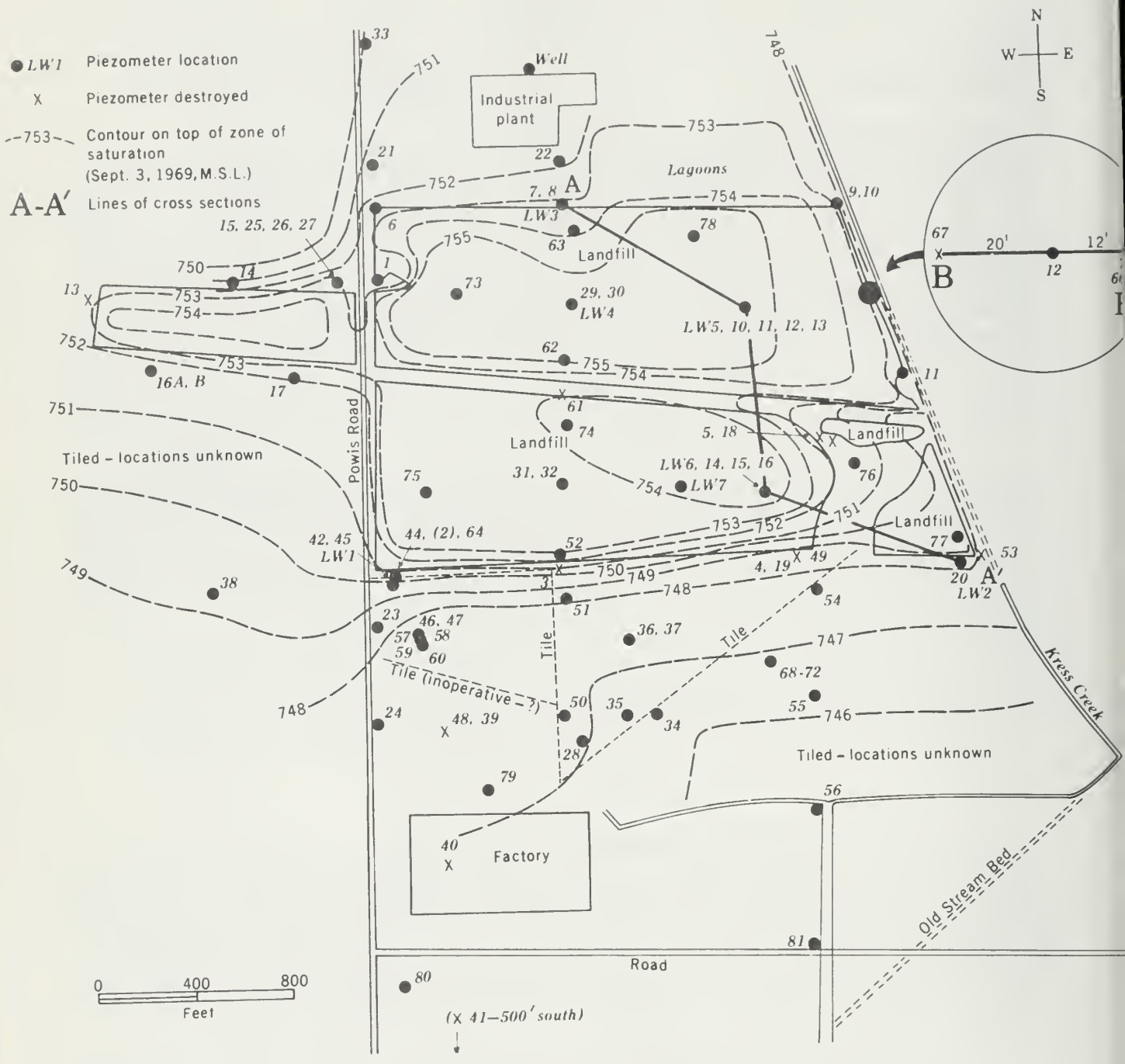



Fig. 3 - Plan view of the old Du Page County landfill showing locations of borings and the top of the zone of saturation.

Figure 3 is a plan view of this landfill and the surrounding area, showing the location of the borings and the contours of the top of the zone of saturation. A ground-water mound 6 feet high has developed in the landfill, and ground-water movement is away from the landfill in all directions.

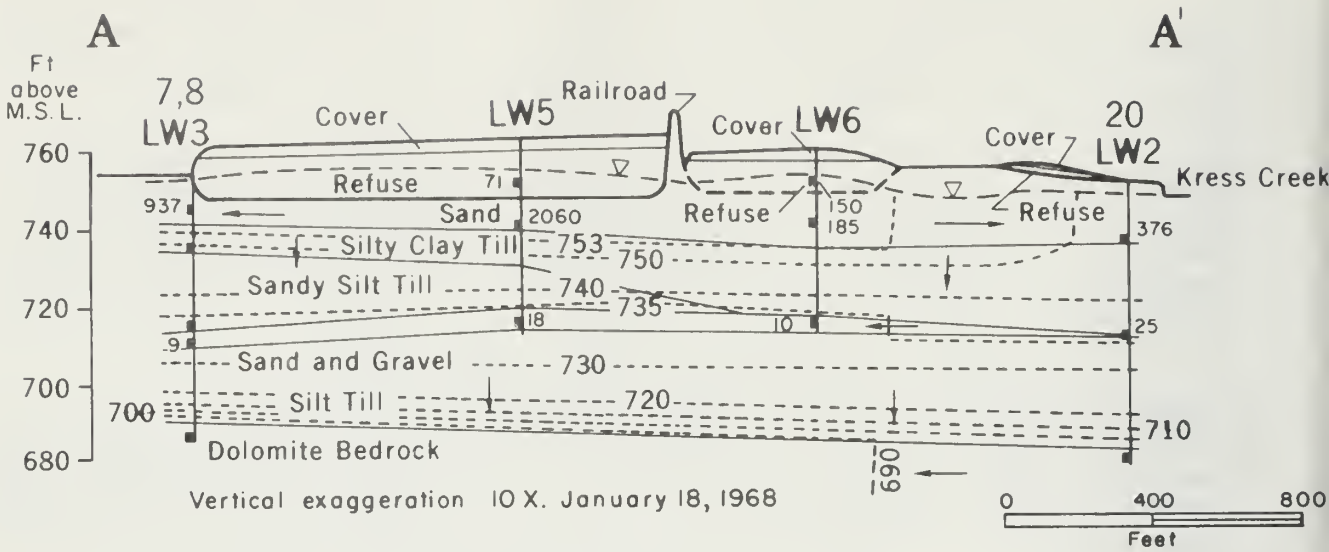
Ground-water mounds have also formed beneath two of the other disposal sites studied. Such mounds form where infiltrated precipitation is restricted from free lateral flow by the surrounding earth materials at the margins of the landfill. Commonly the ground water is discharged as springs or seeps at the edge of the landfill, where the ground-water mound intersects land surface.

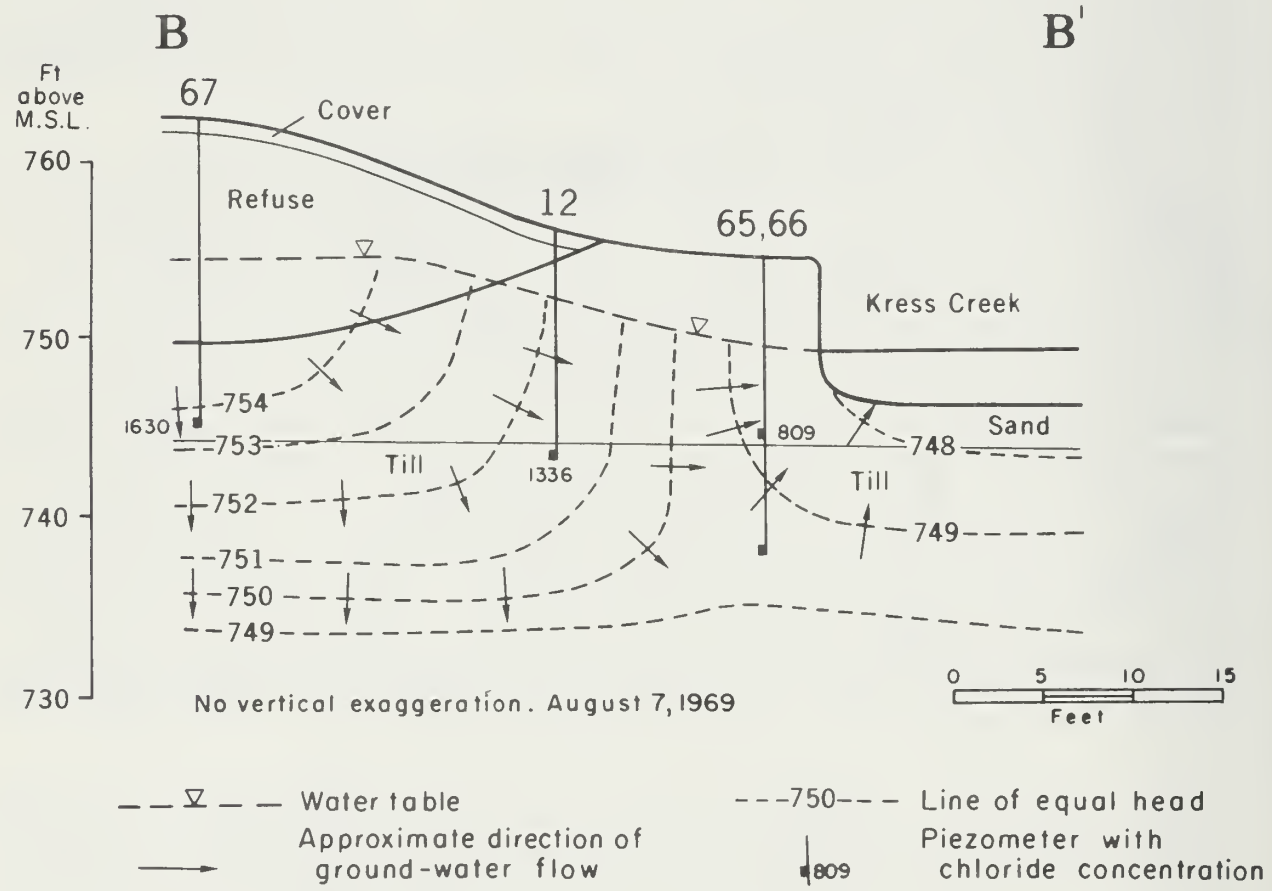
Figure 4 shows vertical sections across the filled area, its lithology, and the equipotential lines. Movement is predominantly lateral but is somewhat downward through the surficial sand. There is a nearly vertical gradient downward through the underlying till. Section B-B' shows the influence of Kress Creek on the configuration of the flow system along the east side of the landfill.

Of the 28.58 inches of rain that fell on this landfill from October 1, 1968, through September 30, 1969, approximately 15.6 inches infiltrated the landfill. Based on the area involved, this is a rate of 90,000 gallons per day. We calculate that 87 percent of this infiltrated water moved laterally out of the landfill through the surficial sands and 13 percent moved downward through the till beneath the landfill.

Figure 5 presents chloride concentrations in the leachate in the landfill and in the surficial deposits surrounding the landfill. Chloride is perhaps the most mobile and easily detected of the ions in the leachate and therefore is an excellent tracer. Chlorides have moved at least 600 feet, but not more than 900 feet, southward from the landfill. This distance agrees with calculations of the velocity of ground-water movement through the sand. Our data indicate that the biological oxygen demand, the chemical oxygen demand, and the potassium and iron values of the leachate were reduced by approximately two orders of magnitude by the time the leachate had traveled approximately 600 feet south of the old Du Page landfill. Hardness, sodium, calcium, and bromine were reduced by approximately one order of magnitude, and other components of the leachate were reduced by various degrees. Sulfate, phosphate, and nitrate were the only components that showed a definite increase in concentration with distance away from the landfill. Their increase is attributed to the fact that these components cannot exist in the reducing environment caused by the high organic content of leachate, but, as the organic components are attenuated away from the fill and reducing conditions become weaker, the nitrate, sulfate, and phosphate radicals can exist.

Data from a series of wells completed in the upper part of the till beneath the Du Page landfill show that in leachate moving a distance of 4 to 5 feet through the till the chloride content and the total dissolved solids content decreased more than one order of magnitude and the organic material decreased two orders of magnitude. Dissolved solids from the landfill were not detected in the interbedded sand 20 feet below the top of the glacial till, in the dolomite bedrock, or in the creek adjacent to the landfill.




Water table

Approximate direction of ground-water flow

750 Line of equal head

809 Piezometer with chloride concentration

Fig. 4 - Cross sections of the old Du Page County landfill. Selected chloride concentrations and lines of equal head are shown.

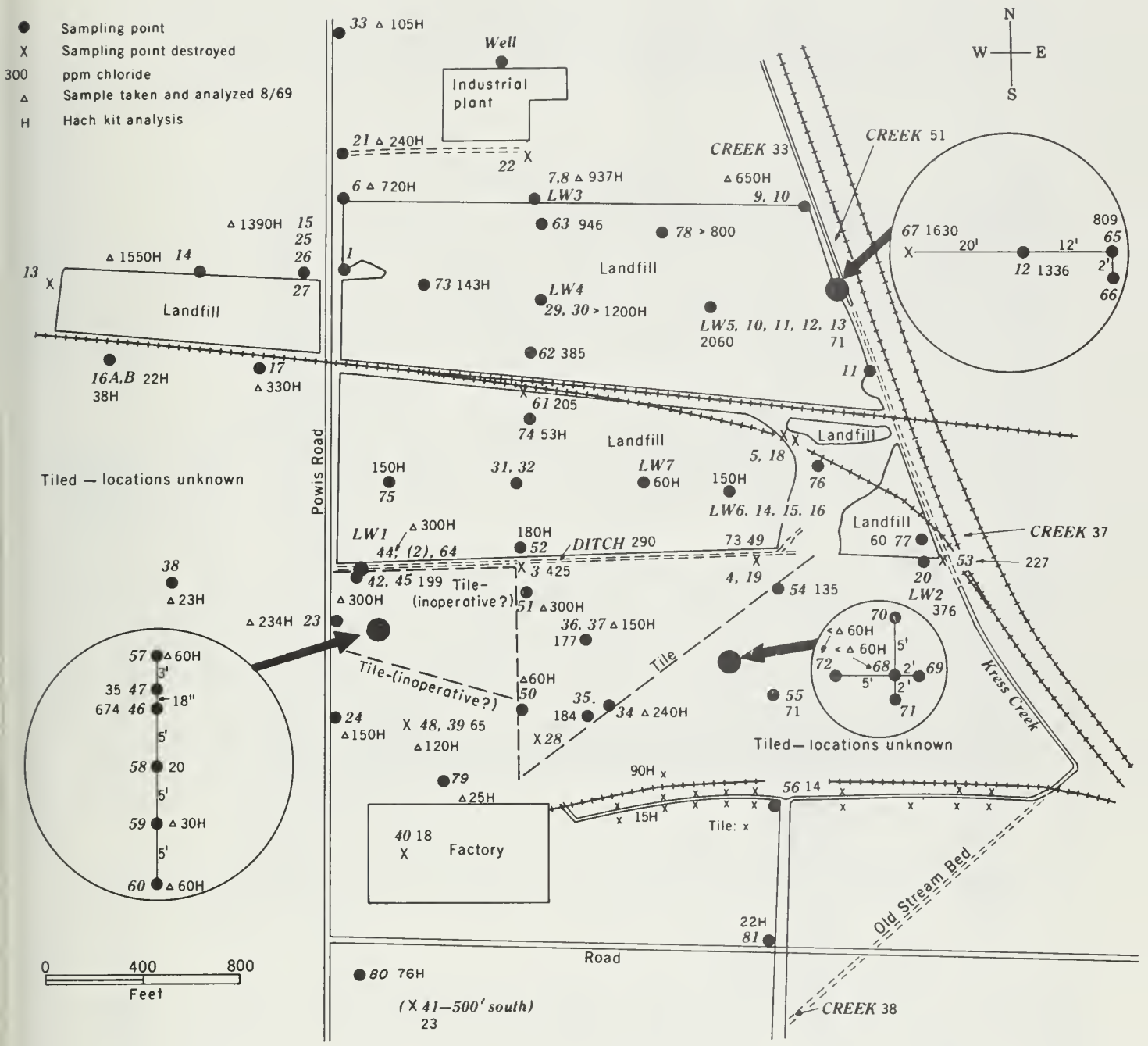



Fig. 5 - Selected chloride concentrations in surficial sand and gravel at the old Du Page landfill.

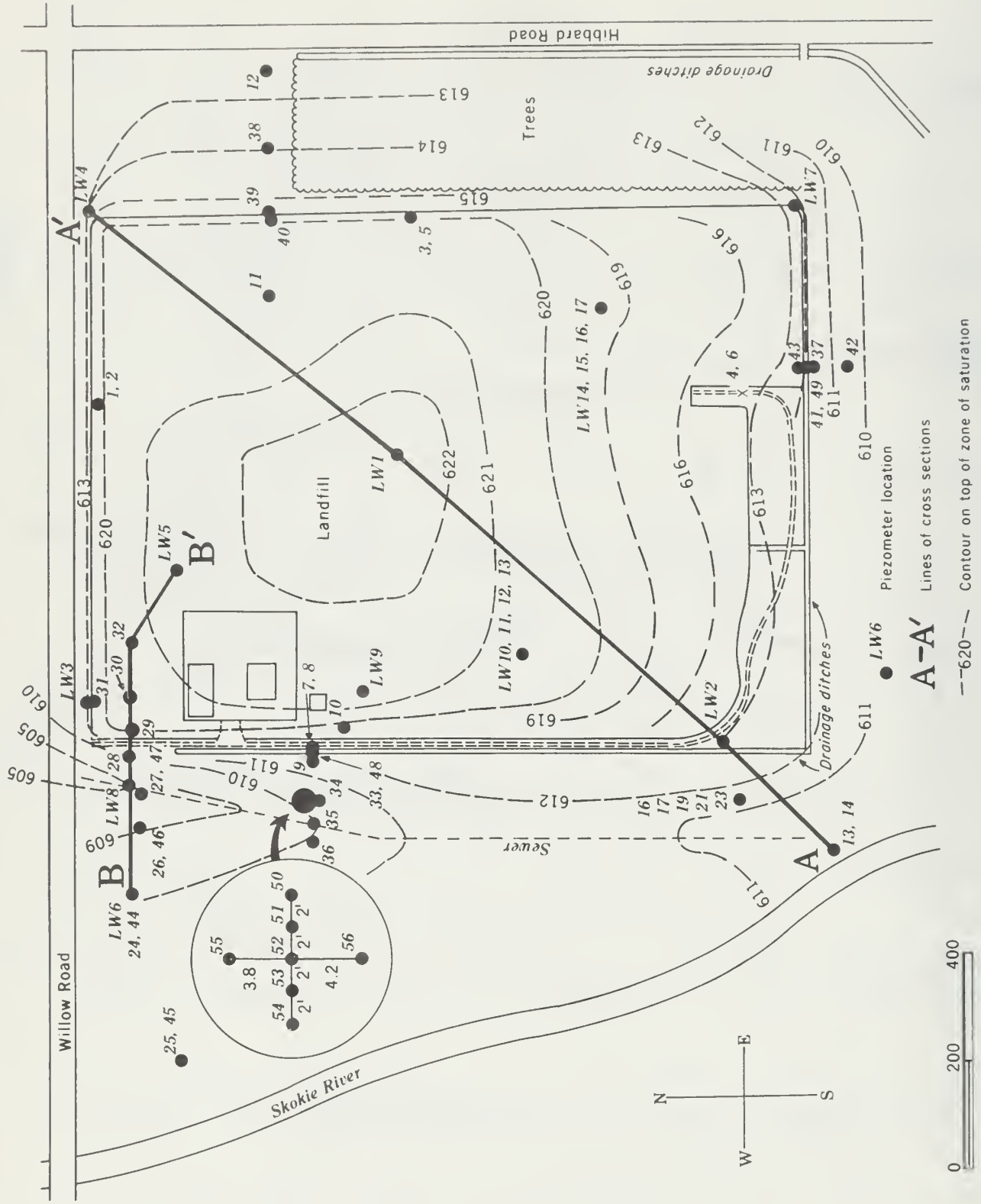



Fig. 6 - Plan view of the Winnetka landfill showing locations of borings and the top of the

Apart from the springs along the side of this landfill, which could probably be considered as no more than a local nuisance, this site has had little effect on the surrounding environment. The ground water in the shallow surficial sand surrounding the landfill has been degraded to some extent, but the sand is not considered an aquifer. Neither the deeper aquifers underlying the landfill nor the creek along the east side of the landfill have been measurably affected.

## Winnetka Landfill

The Winnetka landfill is located in the SE¼ Sec. 19, T. 42 N., R. 13 E., Cook County. The topography is quite flat and the landfill itself is the highest point in the vicinity. Geologic materials present in the area consist of 5 to 11 feet of sandy clay and silt alluvium, underlain by approximately 100 feet of silty clay and sandy till that contain thin interbedded sand and silt stringers. The underlying bedrock is a fractured dolomite aquifer.

Filling was begun in January 1947 and the landfill is still operating. The cover is 1 to 3 feet thick and consists mainly of clay loam and sandy loam. Refuse was dumped in trenches 5 to 6 feet deep, which intersected the top of the zone of saturation. The refuse was piled 6 to 8 feet above the original land surface.

Figure 6 is a plan view of the Winnetka landfill and the surrounding area, showing the location of the borings and contours of the top of the zone of saturation. As at the Du Page County landfill, a ground-water mound 8 to 10 feet high has formed beneath the filled area, and leachate springs are present along the edge of the landfill. The slope on the west side of this mound is quite steep because water is draining into a sewer. Figure 7 shows two cross sections of the fill area, indicating flow through the surficial alluvium and a downward gradient through the underlying till. Lenses of sand and silt within the till section are not shown because they cannot be correlated from boring to boring.

The location of a sewer on the west side of the filled area is shown on cross section B-B' (fig. 7). This sewer distorts the flow system and serves as a collector for part of the water moving out of the west side of the landfill.

Of the 35.20 inches of rain that fell from October 1, 1968, to September 30, 1969, approximately 15.6 inches infiltrated the landfill. Based on the area involved, this is a rate of 28,300 gallons per day. We calculate that approximately 94 percent of this water moved laterally through the alluvium and 6 percent moved downward through the till beneath the landfill.

Figure 8 shows the chloride concentration in water from the surficial alluvium in the vicinity of the Winnetka landfill. Dissolved solids have reached sampling point 12 approximately 270 feet east of the landfill, but they have been intercepted by the sewer and ditches along the west and south sides of the landfill. There is some evidence that dissolved solids from this landfill have migrated downward from the landfill through approximately 19 feet of

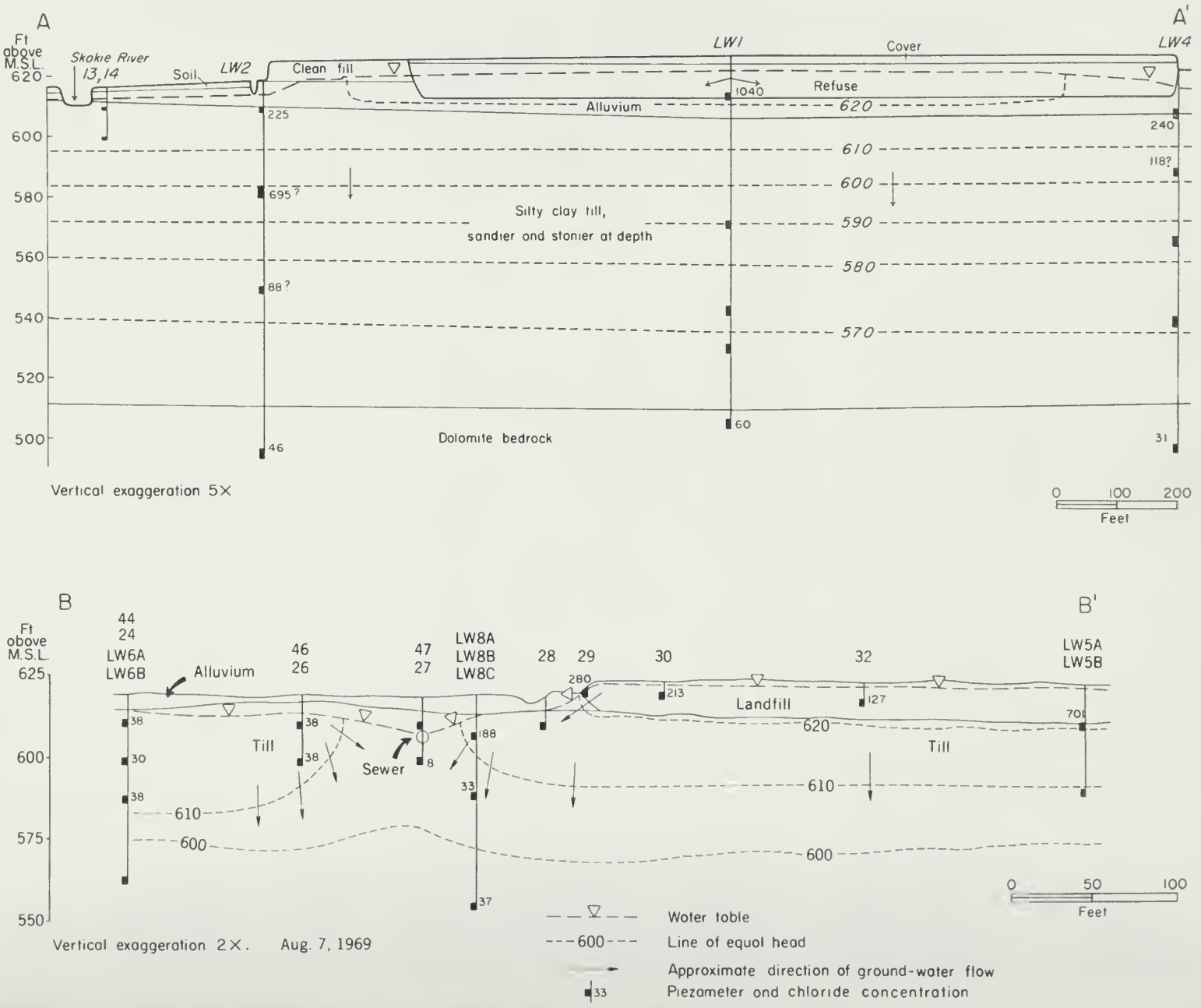



Fig. 7 - Cross sections of the Winnetka landfill and selected chloride concentrations.

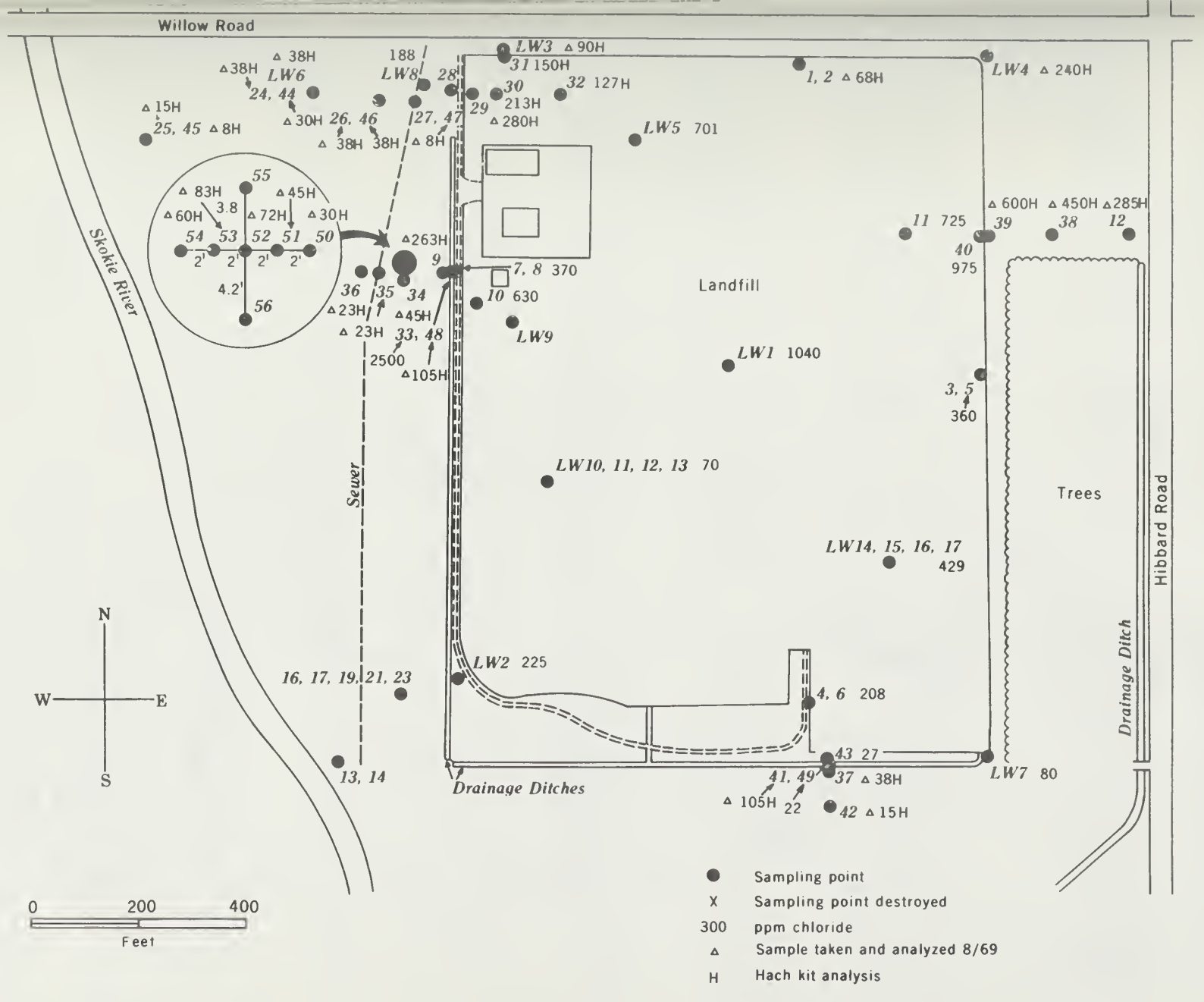



Fig. 8 - Selected chloride concentrations in the alluvium at the Winnetka landfill.

Fig. 9 - Plan view of the Elgin landfill showing locations of borings and the top of the zone of saturation.

alluvium and 14.5 feet of glacial till. The till in this area contains stringers of sand and silt, particularly in its upper part, which may account for the depth reached.

The Winnetka landfill has had very little effect on the surrounding environment. Although surface seepage is present around the edges of the landfill, it has not caused serious problems, and there is no evidence that leachate has moved down far enough to pollute the underlying dolomite aquifer.

## Elgin Landfill

The Elgin landfill is located in the SW¼ Sec. 35, T. 42 N., R. 8 E., Kane County. It is on the west side of the Fox River Valley, and the ground surface slopes to the Fox River on the east. The geologic materials surrounding this site consist of up to 20 feet of coarse-textured sand and gravel, overlying approximately 15 feet of sandy silt till. The till, in turn, overlies 2 to 5 feet of sand and gravel above fractured dolomite bedrock.

The site was a gravel pit before filling began in 1948. Initially, it was used as an open burning dump, but in 1964 it was converted into a sanitary landfill of the trench and fill type. In parts of the area some refuse was emplaced slightly below the top of the zone of saturation. The cover is loam and clay loam approximately 2 feet thick.

Figure 9 is a plan view of the Elgin landfill that shows the location of borings and the contours on top of the zone of saturation. There is no evidence of a ground-water mound at this site, and the water table slopes relatively smoothly to the east and southeast towards the Fox River.

Figure 10 shows two cross sections of the landfill. The sections indicate predominantly lateral movement of the ground water and discharge upward into the Fox River. The Elgin landfill is located in the discharge area bordering the Fox River, and, as the Fox River is one of the major drainages in northeastern Illinois, this is probably a major discharge area.

Of the 26.2 inches of rain that fell from October 1, 1968, to September 30, 1969, approximately 15 inches infiltrated the landfill. Based on the area involved, this is a rate of 66,000 gallons per day. All of this water eventually discharges into the Fox River.

Figure 11 shows the water quality determinations in the vicinity of the Elgin landfill. Correlation between distance from the landfill and the water quality is not as good as at the other sites, probably because variations in the permeability of the shallow sands and gravels allow differential movement of the dissolved solids. Dissolved solids from the landfill are moving out of the site to the east through the uppermost sand and gravel deposit into the Fox River. They have not moved to the west or downward through the till beneath the landfill.

Apart from degrading the ground water in the shallow sand and gravel aquifer between the landfill and the river, the Elgin landfill has had little

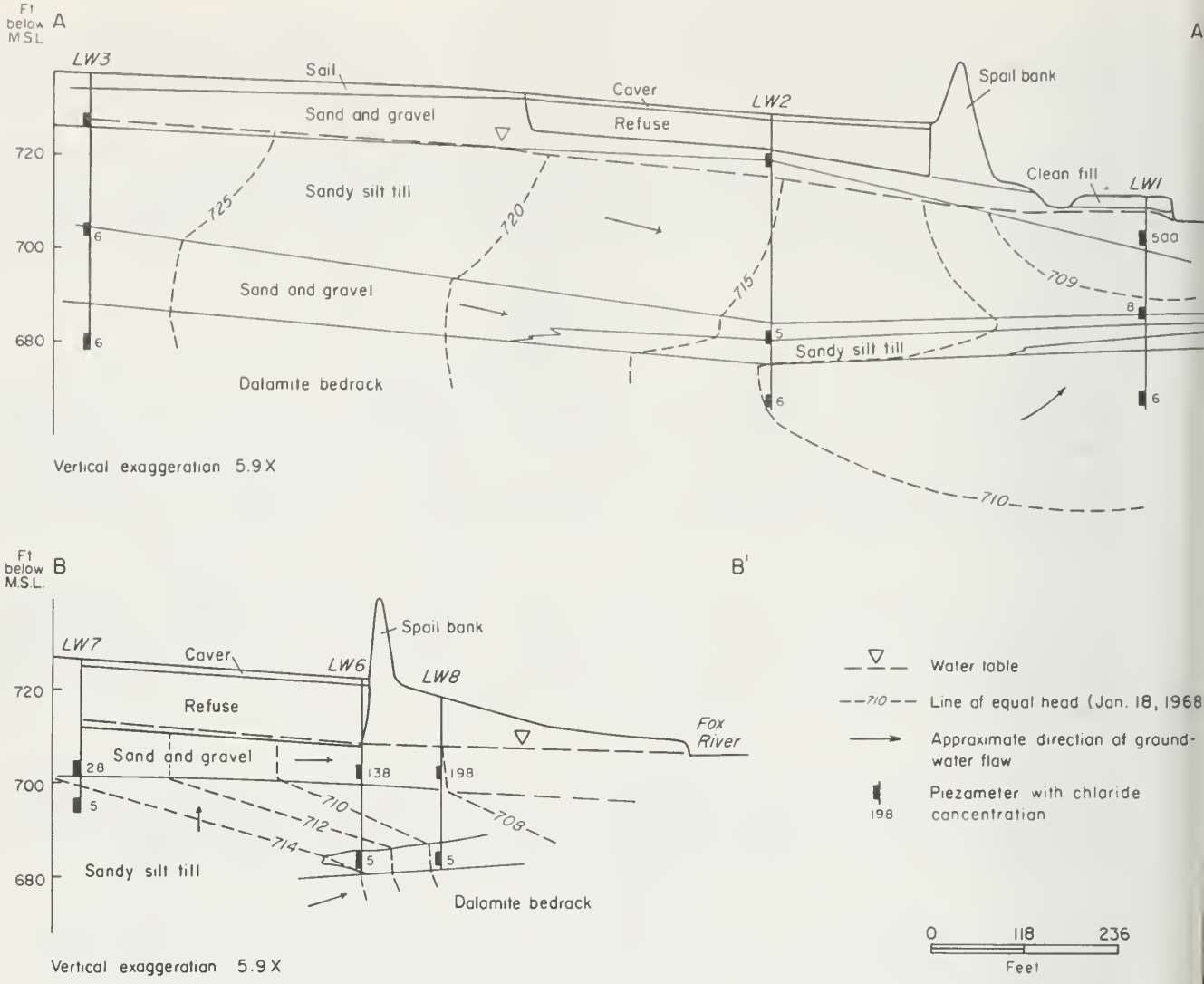


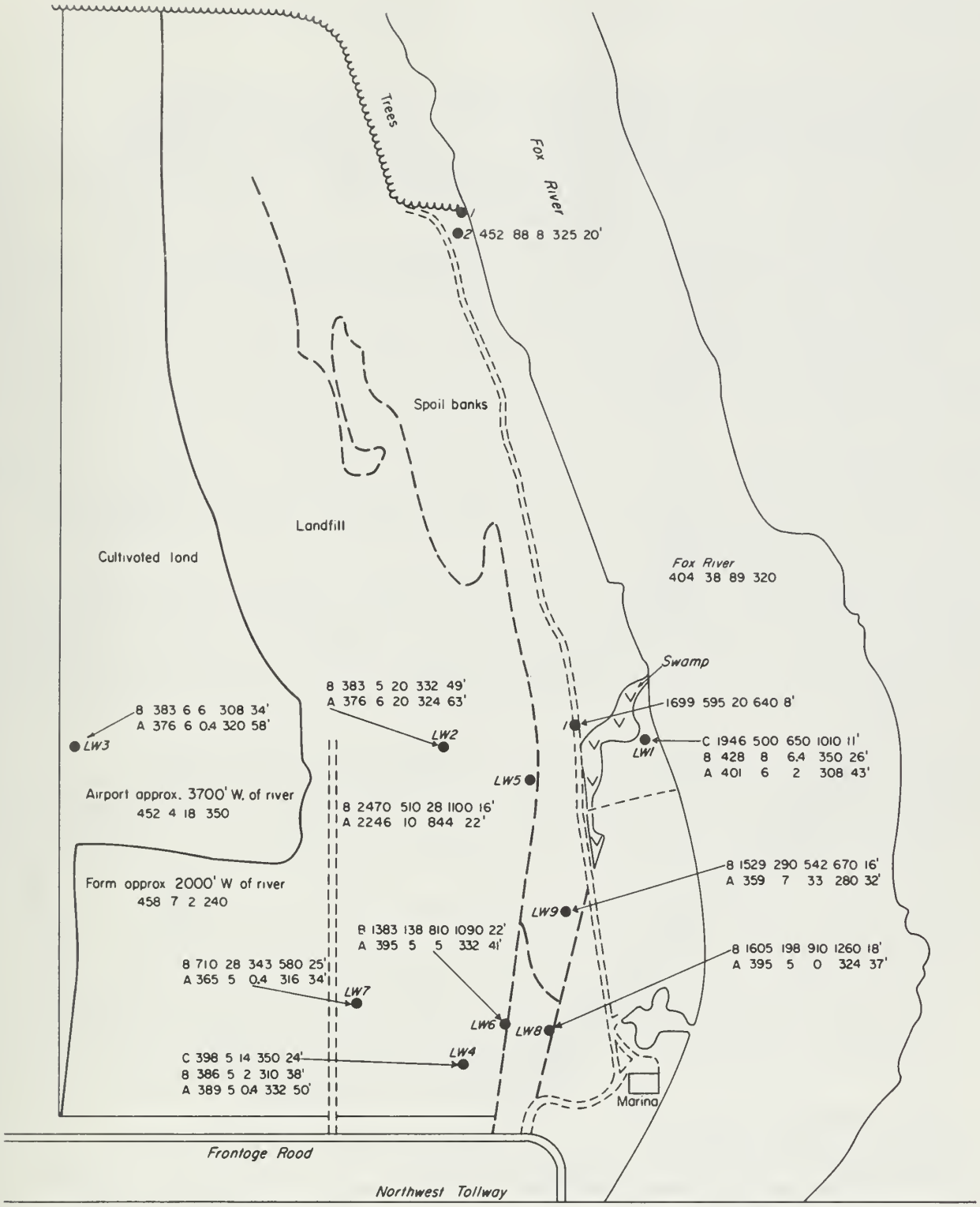

Fig. 10 - Cross sections of the Elgin landfill and selected chloride concentrations.

effect on the surrounding environment, and dissolved solids have not entered the deeper sand and gravel and dolomite units beneath the sandy silt till. These deeper units are aquifers and offer a source of shallow ground water. We estimate the leachate leaving the landfill would raise the dissolved solid content in the Fox River at the point of discharge by approximately 0.30 part per million, half of which is hardness.

## Woodstock Landfill

The Woodstock landfill is located in the NE¼ Sec. 17, T. 44 N., R. 7 E., McHenry County. The topography of the area is morainic. The landfill lies on the top and south flank of an east-west trending upland and in the swampy lowland to the south of this upland.

The geologic materials present consist of a sequence of silty clay till and sandy till interbedded with sand and gravel to a depth of more than




EXPLANATION OF MAP NUMBERS

| Sampling point | TDS (ppm) | Cl (ppm) | $SO_4$ (ppm) | Hardness (ppm) | Depth (or formation) sampled (ft) |
|---|---|---|---|---|---|
| LW6 A | 261 | 40 | 0 | 108 | 58' |

0 100 200 300
Feet

Fig. 11 - Water quality data for the Elgin landfill.

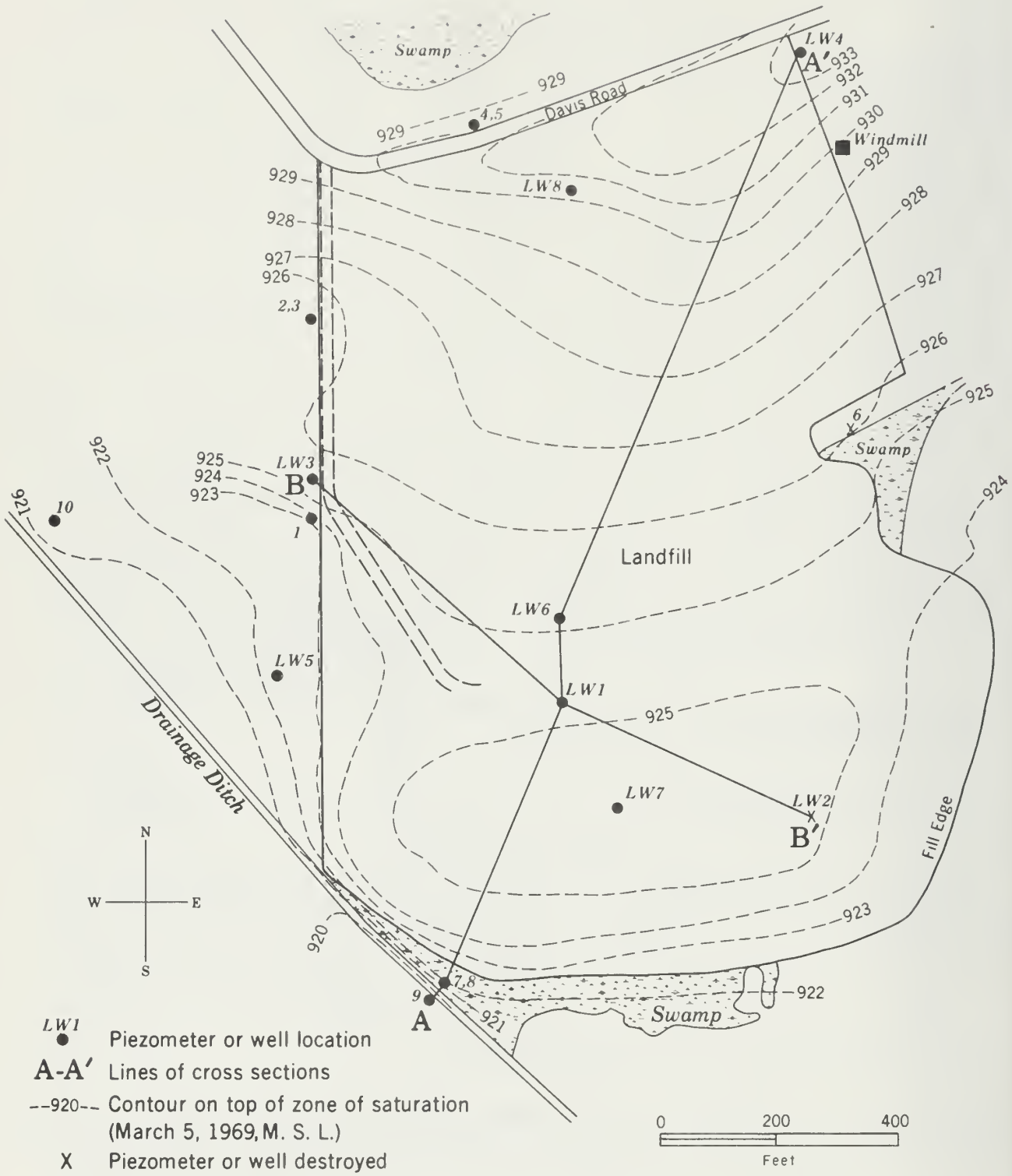



Fig. 12 - Plan view of the Woodstock landfill showing locations of borings and the top of the zone of saturation.

225 feet. In the lowland area, 5 to 19 feet of peat and silt overlie these materials.

The landfill was first operated as an open burning dump, beginning in 1940, and was converted to a sanitary landfill in 1965. The landfill is still in operation. In some parts of the area, refuse was deposited below the top of the zone of saturation. The final cover consists of 2 to 3 feet of loam and silt loam, silty clay loam, and sandy loam.

Figure 12 is a plan view of the Woodstock landfill showing the location of the borings and contours of the top of the zone of saturation. In the northern part of the landfill, gradients on the top of the zone of saturation are away from the upland in all directions. In the southern part of the landfill, the gradient is southward to the swampy areas bordering the landfill or to the drainage ditch west and southwest of the landfill. One effect of the landfill is a steepening of the gradients at the southern edge, which indicates a small ground-water mound lies beneath the landfill.

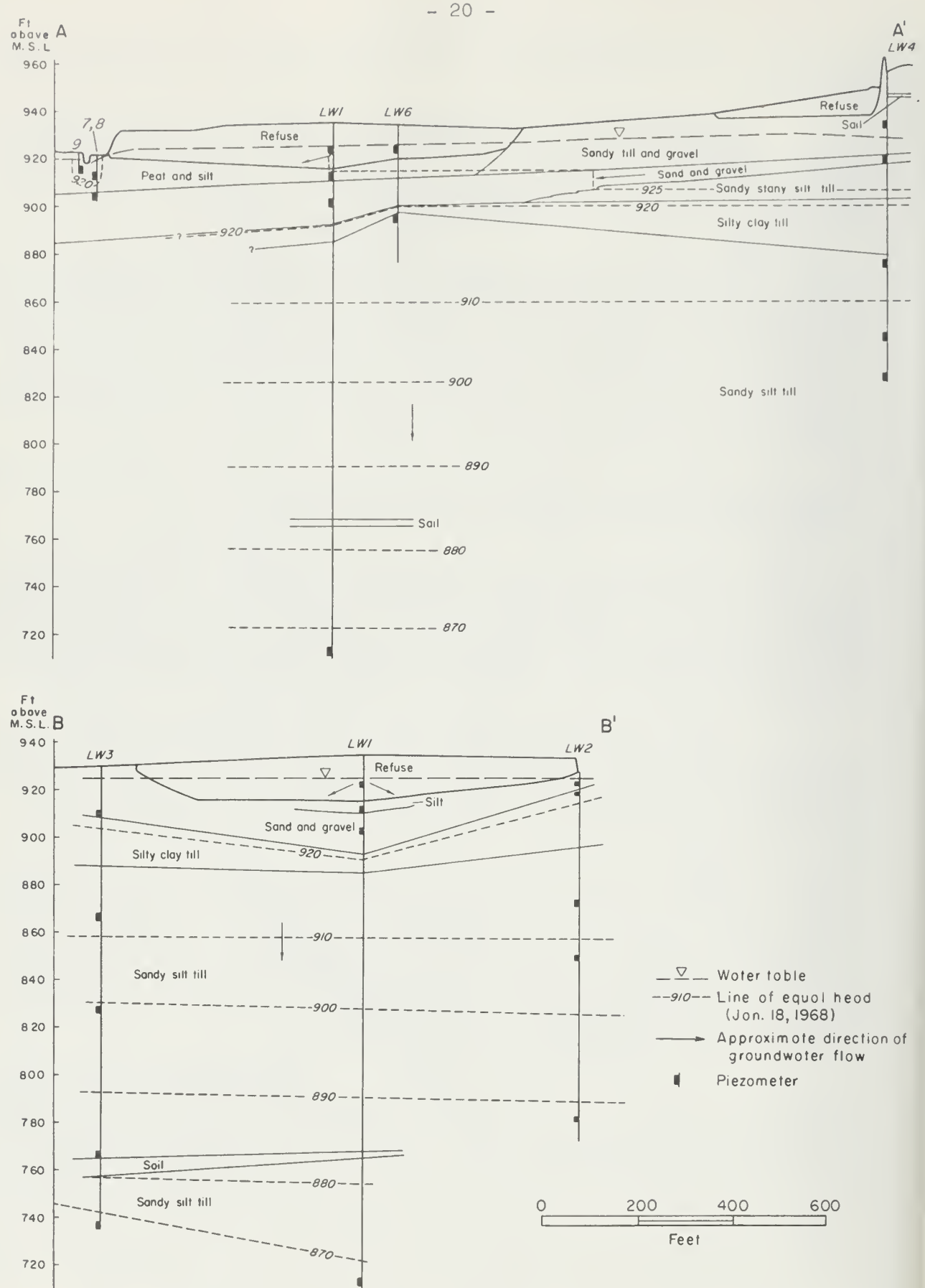
Figure 13 shows two vertical sections across the filled area. There is a strong component of lateral flow in the shallow materials above the silty clay till and a vertical gradient in the silty clay till.

Several interbedded sands and gravels have not been shown on the Woodstock cross sections. These deposits are generally more permeable at Woodstock than at Winnetka and would magnify any horizontal component of the ground-water flow. The drainage ditch west of the landfill area acts in much the same manner as the deep sewer at Winnetka, distorting the flow lines and "collecting" ground water moving from the western side of the landfill.

Of the 24.07 inches of rain that fell from October 1, 1968, to September 30, 1969, approximately 12 inches infiltrated the landfill. Based on the area involved, this is a rate of 22,500 gallons per day. No quantitative evaluation of flow from the Woodstock site was made because of the complex geology and lack of data on the hydrologic properties of the materials.

Water quality data plotted in figure 14 shows the expected inverse relation between the total dissolved solids and the distance from the landfill. There is no movement of dissolved solids downward through the silty clay till. Whether this is because the till has acted as a barrier to their migration, or whether insufficient time has elapsed since the fill was emplaced is not known. Analyses of water in the drainage ditch southwest of the landfill were inconclusive and failed to show whether or not dissolved solids from the landfill have affected this water.

The landfill apparently has had no significant effect on the surrounding environment. The shallow sands and gravels beneath the landfill were degraded by dissolved solids from the landfill; however, the amount of ground water involved is relatively small. After our study had been completed, it was reported that the drainage ditch had been seriously degraded by water moving from the landfill area. Although a detailed investigation was not made, it appeared that, as expansion of the landfill continued to the south, fill material was placed over a broken tile that drained directly into this ditch and that leachate moving through this tile had caused the subsequent problems.




Verticol exoggerotion 5 X

Fig. 13 - Cross sections of the Woodstock landfill.

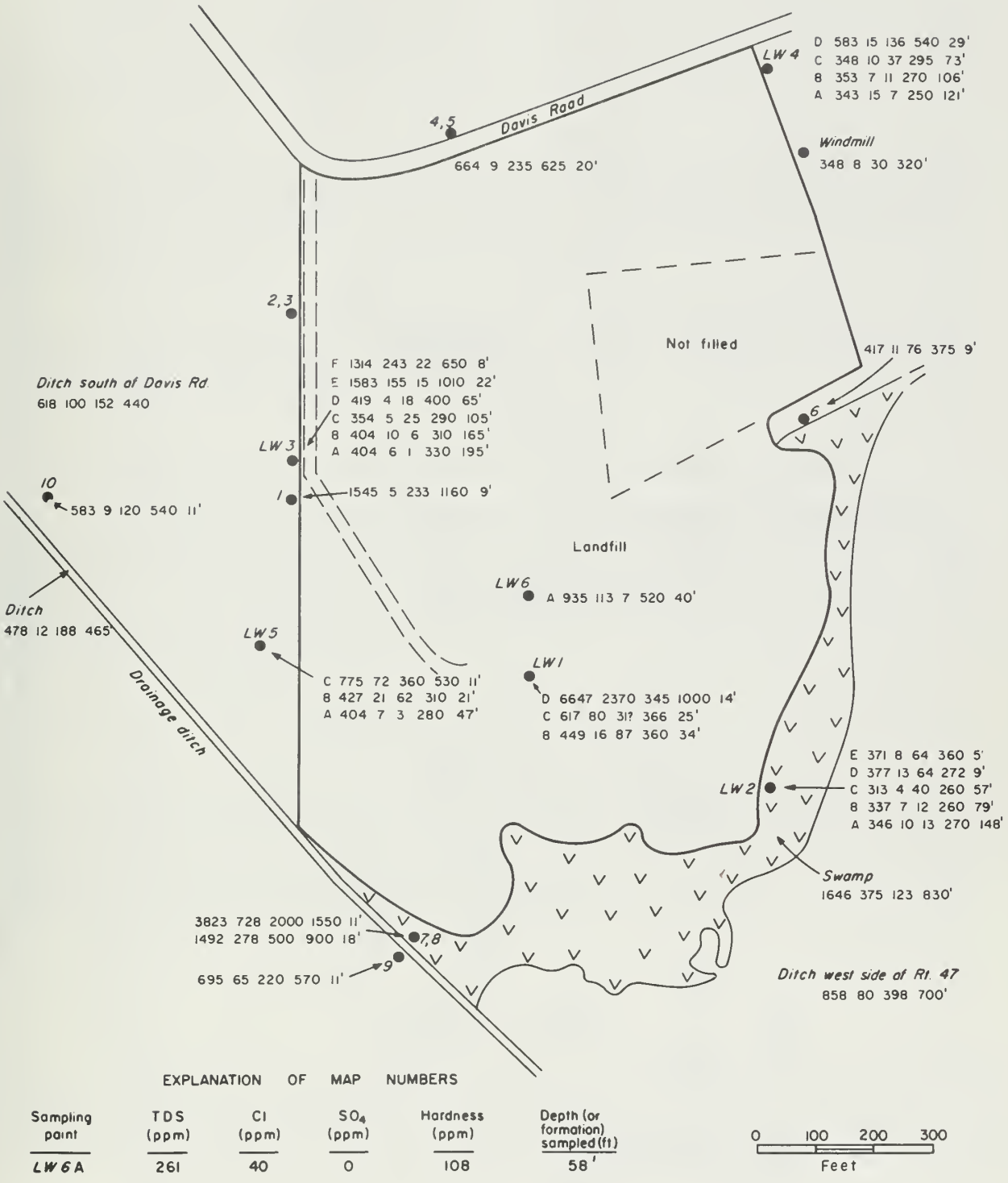



Fig. 14 - Water quality data for the Woodstock landfill.

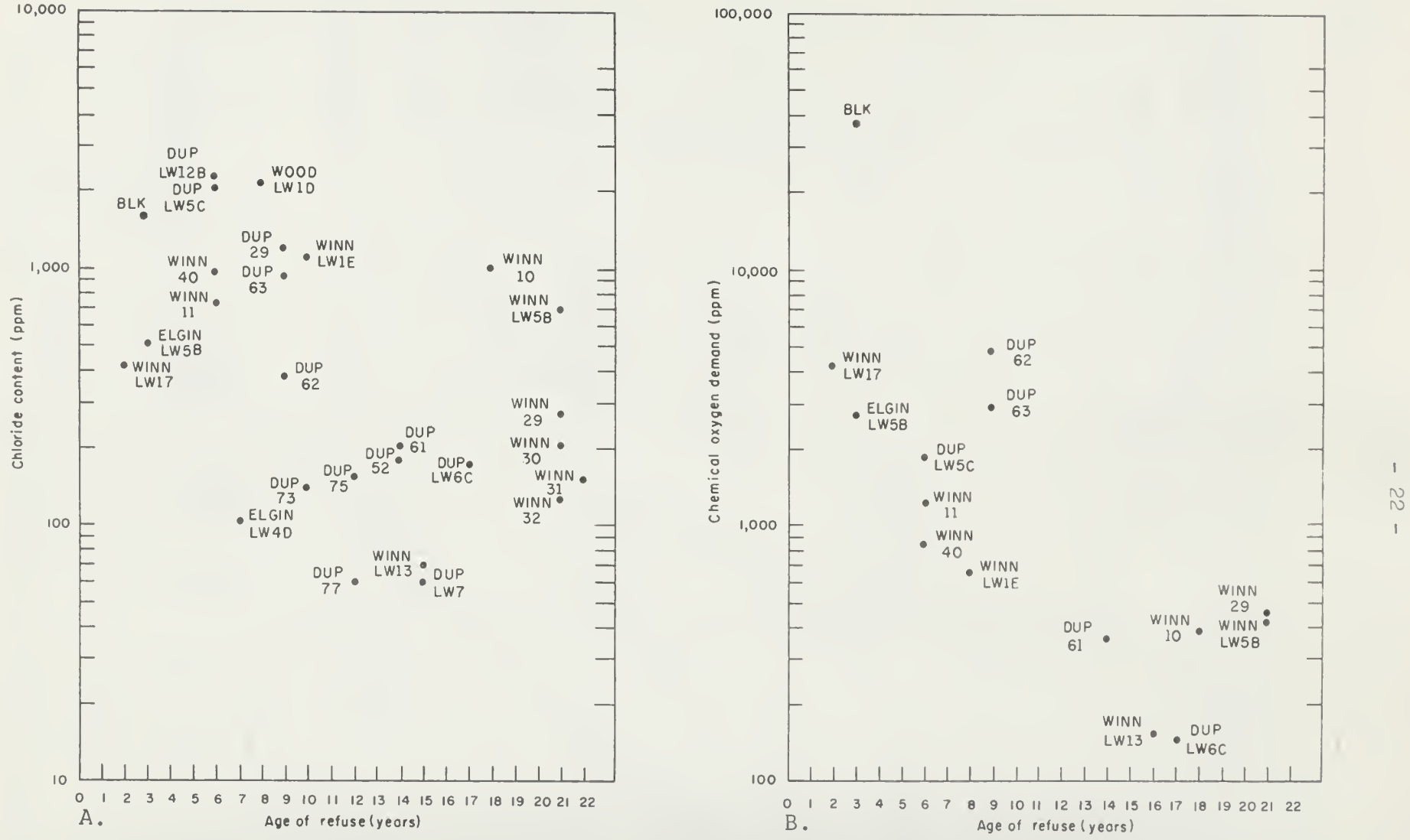



Fig. 15 - (A) Relation between refuse age and chloride content. (B) Relation between refuse age and chemical oxygen demand.

### Blackwell Forest Preserve Landfill

The Blackwell Forest Preserve landfill, located near Warrenville in Du Page County, was begun in October 1965 and is to be made into a winter sports hill, which will eventually be about 150 feet high and cover 30 acres. The base of the landfill is lined with 10 feet of silty clay till, and 15-foot berms are being constructed along the sides, which will completely enclose the refuse.

Only one observation well was installed in this landfill. At the time of sampling, when the refuse had been in place for approximately 39 months, the well contained 5 feet of water. This water rises and falls in response to rainfall, and an additional 15 feet of water accumulated during the winter of 1970.

Leachate collected from this well had a biological oxygen demand (20 days) of 54,610 parts per million and a total dissolved solids content of 19,144 ppm. This highly concentrated leachate is typical of that found in relatively young refuse.

### Variations in Composition of Leachate with Age of Refuse

Chloride content and chemical oxygen demand of leachate samples are plotted against age of refuse on figures 15A and 15B. The correlation is poor. Much of the scatter can be attributed to normal variations in the composition of the leachate. Refuse more than 20 years old evidently can still have a high content of dissolved solids, indicating that stabilization of landfills is a long process.

### Analyses of Landfill Gases

In the course of this study, 20 samples of landfill gases were collected and analyzed for carbon dioxide, oxygen, nitrogen, and methane. The analyses show that gas with a maximum of 84 percent methane is being produced from refuse buried in 1955 at the old Du Page County landfill and that some methane is still being produced from the oldest (1947) part of the Winnetka landfill, indicating that decomposition is still underway.

## DESIGN OF LANDFILLS

Landfill sites may be upgraded by various engineering techniques if they do not have naturally protective environments. These techniques may (1) allow the migration of leachate under acceptable conditions, (2) provide for recovery of the leachate, or (3) eliminate the production of leachate altogether.

For any landfill design, the type of earth materials present at the site must be determined and the ground-water flow system known if the landfill is to function properly and if the capacity of the environment for self-purification is to be used advantageously.

Engineering techniques that could be used to make a landfill safe include containment of leachate by installing an impervious lining in the site before the fill is emplaced, reduction of infiltration through the landfill by covering and grading the surface, collection of leachate by tiles or pumping systems, venting of landfill gases, and treatment of leachate.

Other factors that should be considered in landfill design are the type of cover material to be used, the settlement of the fill, the possibility of construction over the completed landfill, and the final use projected for the completed landfill area.

## CONCLUSIONS

If ground-water pollution alone is considered, approximately 80 percent of northeastern Illinois would probably be suitable for sanitary landfilling with little or no site modification, because the surficial materials are fine textured, have low permeability, and would restrict the movement of leachate. Another 10 percent of the land area would be suitable because of its favorable location within the hydrogeologic flow system. Sites in the remaining 10 percent of northeastern Illinois may require a considerable amount of modification. Unfortunately, a disproportionately large percentage of the sites proposed as sanitary landfills fall into this last category, a group that includes mined-out quarries and gravel pits. Such sites are easily filled, and, when filled, increase substantially in value. However, they are not safe landfill sites unless modifications are made.

Under typical landfill conditions in northeastern Illinois about half the yearly precipitation will infiltrate the landfill surface. This water, in the form of leachate, runs off on the land surface or enters the ground-water reservoir. If the water infiltrates the fill and moves downward, ground-water mounds are formed. Three of the disposal sites studied had such mounds. Ground-water mounds may result in the formation of springs around the margin of the filled area.

In humid areas requirements that refuse be placed above the top of the zone of saturation are not likely to prevent the production of refuse leachate. Such requirements may in fact lead to locating landfills in less satisfactory environments. For instance, in upland recharge areas the top of the zone of saturation is deep, but such areas generally make poor landfill sites because of the presence of permeable materials that allow downward migration of leachate and lateral migration of landfill gas.

Fine-textured sediments, such as glacial tills, are much more effective than more permeable sands and silts in removing dissolved solids from leachate. Data from the old Du Page County landfill show that dissolved solids in leachate that travels through 5 feet of sandy clay till having a permeability of $10^{-7}$ centimeters per second are reduced approximately the same amount as solids in leachate that travels through 600 feet of outwash sand and silt having a permeability of approximately $10^{-3}$ centimeters per second.

At each of the sites studied, ground-water flow patterns are relatively simple, and the hydrogeologic factors responsible for these patterns can, in most cases, be readily inferred. Although the water-quality determinations varied considerably, the over-all distribution of the dissolved solids in the vicinity of these various landfills was, in general, in accord with what would have been predicted if the system of ground-water flow had been known.

The results of this investigation and other studies indicate that environmental problems associated with solid waste disposal are not nearly as serious as those posed by liquid waste disposal operations and pollution of the air through gaseous waste disposal. The technology is available to handle all of the problems associated with solid waste that are likely to occur, with relatively little expense and inconvenience. The major problem appears to be that of implementing this technology and regulating and supervising current and future disposal operations.

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